[Continued on next page]

(54) Title: VIDEO SIGNAL POST-PROCESSING METHOD
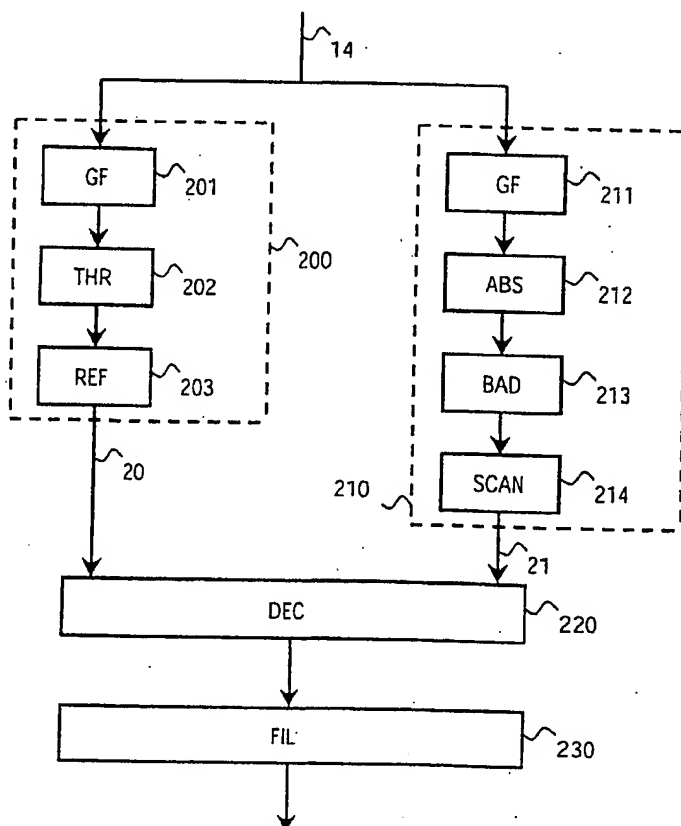
(57) Abstract: The present invention relates to a method of post-processing pixels contained in a sequence of digital images. Said method comprises a step (200) of detecting pixels belonging to natural contours (20) inside an image. It also comprises a step (210) of detecting an investigation zone (21) corresponding to a coding block. It comprises a filtering decision step (220) such that a current pixel is filtered if it has not been detected as being a natural contour pixel (20) and if it belongs to an investigation zone (21) containing at least one natural contour pixel (20). Finally, the method comprises a pixel filtering step (230), of the median filtering type, for the pixels to be filtered.

WO 03/081534 A1

Video signal post-processing method

FIELD OF THE INVENTION

The present invention relates to a method of post-processing pixels contained in a sequence of digital images, said method comprising a step of detecting pixels belonging to natural contours inside an image and a pixel filtering step.

5   It also relates to a device implementing such a post-processing method.

The present invention in particular finds its application in the field of video coding. The coding technique is based for example on the MPEG (from the English "Moving Pictures Expert Group") standard or an equivalent standard, by virtue of which a sequence of digital images is previously coded and then decoded in the form of blocks of data, the present

10   invention allowing the correction of the data included in the decoded sequence of digital images in order to attenuate the visual artifacts caused by the block-based coding technique. Thus it can advantageously be integrated in video decoders or in television receivers.

BACKGROUND OF THE INVENTION

15   The coding of an image sequence at low bitrate, using the MPEG coding technique or equivalent techniques, introduces visual artifacts into the decoded images. Amongst the most usual artifacts there can first of all be cited blocking artifacts which result in a visible division of the image into blocks, generally of 8 x 8 pixels. A second type of artifact consists of ringing artifacts. These are multiple echoes of natural contours, this visual

20   defect also being referred to as the Gibbs phenomenon. Since these artifacts can be a great nuisance, it is necessary to correct them.

Though there exist many methods for correcting blocking artifacts, there are on the other hand very few methods for correcting ringing artifacts. The international patent application WO 2001/24115 (internal reference: PHF99584) describes such a method for the

25   post-processing of pixels contained in a sequence of digital images intended to reduce ringing artifacts. This post-processing method comprises a step of detecting pixels belonging to natural contours inside an image using for example Sobel filters.

It also comprises a step of deciding on the filtering of a current pixel according to the surroundings of said pixel. For this purpose, the post-processing method is able to

divide the image into zones of 4 x 4 pixels, the current pixel belonging to a central zone, and the East, North, West and South zones adjacent to the central zone being taken into consideration. Thus a current pixel in the central zone is filtered if the following three cumulative conditions are satisfied:

- it does not belong to a natural contour,

- the number of natural contour pixels present in the 5 zones is less than a first predetermined value Nmax,

- the number of natural contour pixels present in each zone is greater than a second predetermined value Nmin.

Finally, the post-processing method comprises a step of median filtering of a pixel to be filtered thus determined, from a vicinity of said pixel. The vicinity of current pixel comprises certain pixels amongst a set comprising said current pixel and the East, North, West and South pixels which are adjacent to it, depending on the fact that some of said adjacent pixels are natural contour pixels or not.

Such a post-processing method is however relatively complex to implement since it requires having values of pixels belonging to 5 different zones.

SUMMARY OF THE INVENTION

The aim of the present invention is to propose a method for the post-processing of pixels contained in a sequence of digital images, which is more simple to implement.

To this end, the post-processing method according to the invention is characterized in that it also comprises a step of detecting an investigation zone corresponding to a coding block, a current pixel being filtered if it has not been detected as being a natural contour pixel and if it belongs to a coding block containing at least one natural contour pixel.

Thus the present invention takes account of the values of pixels belonging to a coding block, generally of 8 lines of 8 pixels, rather than the values of pixels belonging to 5 different zones of 4 lines of 4 pixels. The present invention is therefore able to make a filtering decision from a smaller number of pixels more easily accessible since they are distributed over 8 lines instead of 12, which makes the implementation of the post-processing method more simple, from a memory access point of view.

In addition, the present invention stems from the following analysis. The ringing artifacts result from an intense quantization of the transformed DCT (standing for "Discrete Cosine Transform") coefficients inside the coding block. Starting from this

assumption, it is possible to deduce that the ringing artifacts, which correspond as we have seen previously to an echo of a natural contour, can be found only in an investigation zone corresponding to a coding block where at least one natural contour is present. The consequence of this analysis is that the investigation zones not containing any natural contour

5   are not filtered, which could happen with the method of the state of the art where the filtering decision did not take account of the coding blocks. The post-processing method according to the invention is thus simplified further since it processes fewer pixels by eliminating all the pixels in the investigation zones which do not contain a natural contour. It is also more effective because it takes account of the block-based coding technique.

10   The present invention also relates to the device implementing the pixel post-processing method according to the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

15   The invention will be further described with reference to examples of embodiments shown in the drawings to which, however, the invention is not restricted.

          - Fig. 1 depicts the functioning of a complete chain for processing a digital video signal,

          - Fig. 2 is a schematic diagram of the pixel post-processing method according

20   to the invention,

          - Fig. 3 depicts a vicinity of a current pixel to be filtered, and

          - Fig. 3 depicts the detection of a chrominance sample belonging to natural contours from a luminance sample.

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DESCRIPTION OF PREFERRED EMBODIMENTS

          The present invention relates to a method for the post-processing of pixels contained in a sequence of digital images. Said method is intended to improve the visual quality of the digital images when these have been previously coded and then decoded

30   according to a block-based coding technique.

          The post-processing method was developed in particular for a coding technique based on the MPEG-2 or MPEG-4 standard. It nevertheless remains applicable for any other block-based coding technique such as H.261, H.263 or H.26L for example.

Fig. 1 illustrates the functioning of a complete chain for processing a digital video signal comprising coded digital images (10). Said chain comprises a video decoder (11) comprising a decoding module (12) and intended to transmit a decoded image (14) via a channel (13) to a television receiver (15) intended to display the digital image thus decoded.

5   A correction or post-processing device (16), in contradistinction to a preprocessing of the signal which would have taken place before the coding of said signal, improves the visual quality of the digital image with a view to its display on the screen (17). The post-processing device is situated either at the output of the video decoder as depicted in dotted lines or at the input of the television receiver as depicted in solid lines.

10   In a first embodiment, the post-processing method is implemented at a television receiver. The pixel post-processing method illustrated in Fig. 2 thus comprises the following steps:

- First of all a step (200) of detecting pixels belonging to natural contours inside a decoded image (14). For this purpose, the detection step is based on a gradient

15   filtering GF (201) preferably using two-dimensional Sobel filters, a filter Sh in the horizontal direction and a filter Sv in the vertical direction. It will be clear however to a person skilled in the art that other gradient filters can be used for detecting natural contours. The Sobel filters used are as follows:

$$Sh = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \text{ and } Sv = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

20   The Sobel filters are applied to the luminance component Y of the pixels of an image, the detection step resulting in an image of horizontal filtered data $Gh = Y * Sh$ and an image of vertical filtered data $Gv = Y * Sv$.

Then a thresholding THR (202) is applied to each of the two maps of filtered pixels. All the pixels $p(i,j)$ whose total filtered luminance value $G(i,j) = Gh(i,j)^2 + Gv(i,j)^2$ is

25   greater than a predetermined threshold value T1 have the final value 1, i.e. they are detected as being natural contour pixels (20), the others having the value 0. The predetermined threshold value T1 is preferably an empirical value determined in an absolute manner from a certain number of sequences of digital images tested, equal, for example, to 12000 for luminance values of between 0 and 255. This thresholding can be refined as follows, a pixel

30   being detected as a natural contour pixel if:

G[i,j] > T1 AND

(

$(((|Gv[i,j]| \geq |Gh[i,j]|)$ AND $(G[i,j] \geq G[i,j-1])$ AND $(G[i,j] \geq G[i,j+1]))$

OR

$(((|Gh[i,j]| \geq |Gv[i,j]|)$ AND $(G[i,j] \geq G[i-1,j])$ AND $(G[i,j] \geq G[i+1,j]))$

$)$

5   The predetermined threshold value can also be determined in a relative manner as being equal to T2, whose calculation method is more complicated:

$$T2 = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m}\sqrt{Gh(i,j)^2 + Gv(i,j)^2}}{n \cdot m}$$

where n is the number of lines and m the number of columns in the image.

In addition, the detection step is able to take into consideration the

10   environment of a natural contour pixel thus detected. Thus it comprises a refinement substep (203) such that, if a vicinity comprising the 8 pixels surrounding such a pixel contains no other natural contour pixel, then said pixel is no longer assimilated to a natural contour pixel. Thus an isolated natural contour pixel is not considered to be a true natural contour pixel (20).

15   - The post-processing method also comprises a step (210) of detecting an investigation zone (21) corresponding to a coding block. At the television receiver, no information relating to the decoding is accessible. It is therefore necessary to analyze the content of at least one image in order to determine the position and size of the investigation zone corresponding to a coding block. Such a block generally comprises 8 lines of 8 pixels in

20   the case of the MPEG standard but the investigation zone may have a different size after any resampling of the image during decoding, taken by assumption hereinafter at a size of 8 lines of 10, 12 or 16 pixels in accordance with the main resampling formats allowed by the MPEG standard. A simple adaptation can be made to the method described below for taking account of other formats.

25   The step of detecting the investigation zone is preferably based on the method described in the International patent application WO 01/20912 (internal reference: PHF99579). The step of detecting the investigation zone comprises a horizontal and vertical gradient filtering substep GF (211) for the luminance pixels y(i,j) of a digital image or for a portion of a digital image in the sequence, where i and j correspond to the position of the

30   pixel in the image. The gradient filtering step uses for example the previously mentioned Sobel filters. There are then obtained tables of pixels filtered horizontally xh(i,j) and

vertically xv(i,j), whose absolute value ABS (212) is taken in order to obtain xah(i,j) and xav(i,j).

The investigation zone detection step also comprises a substep of detecting blocking artifacts BAD (213). Thus a vertical blocking artifact is detected if:

$$\begin{cases} xa_h[n,j] > xa_h[n,j-1] + \dfrac{\overline{xa_h}}{2} \\ xa_h[n,j] > xa_h[n,j+1] + \dfrac{\overline{xa_h}}{2} \end{cases} \quad \forall n \in [i, i+7]$$

Likewise, a horizontal blocking artifact is detected if:

$$\begin{cases} xa_v[i,m] > xa_v[i-1,m] + \dfrac{\overline{xa_v}}{2} \\ xa_v[i,m] > xa_v[i+1,m] + \dfrac{\overline{xa_v}}{2} \end{cases} \quad \forall m \in [j, j+k-1] \text{ with } k = 8, 10 \text{ or } 12$$

An analysis step SCAN (214) then determines the size and position of the investigation zone corresponding to a coding block.

For this purpose, when a vertical blocking artifact is detected for a column j, the value vTab8(j%8), vTab10(j%10) and vTab12(j%12) of 3 vectors vTab8, vTab10, vTab12 comprising 8, 10 and 12 values is incremented, a%b or a modulo b being the operation, the result of which is the remainder of the division of a by b. Likewise, when a horizontal blocking artifact is detected at line i, the value hTab(i%8) of a vector hTab comprising 8 values is incremented.

In parallel and in order to determine the size of the investigation zone, a general counter is created and then incremented at the reading of each pixel of an image or portion of an image. It is set to zero when a vertical blocking artifact is detected. The principle of the determination is to know whether a current vertical blocking artifact is distant from the last vertical blocking artifact of 8, 10 or 12 pixels. Thus, if the value of the general counter between two vertical blocking artifacts is equal to 8, 10 or 12, then one of the counters grid8, grid10 and grid12 relating respectively to a width of the investigation zone of 8, 10 and 12 pixels is incremented. The width k of the investigation zone then corresponds to the counter which has the greatest value.

This indication gives the vector vTabk, k = 8, 10 or 12, to be taken into consideration from amongst the three possible vectors, and the origin of the investigation zone is determined by seeking the maximum values in the vectors hTab and vTabk.

Other methods of detecting the investigation zone are also possible such as the one, for example, described in the European patent application n° 1202577 (internal reference: PHFR000106).

5   - The post-processing method then comprises a filtering decision step (220): a current pixel is filtered only if it has not been detected as being a natural contour pixel and if it belongs to an investigation zone containing at least one natural contour pixel.

- Finally, the post-processing method comprises a filtering step (230): the pixels which satisfy the criteria set out above undergo a filtering. This filtering is preferably a median filtering. A mean filtering can also be envisaged.

10   This median filtering is able to replace a current pixel with a pixel from its vicinity. The vicinity of the current pixel comprises certain pixels amongst a set of pixels illustrated in Fig. 3 and comprising said current pixel (30) and the East (31), North (32), West (33) and South (34) pixels which are adjacent to it.

If none of the pixels in the vicinity is a natural contour pixel, then the value Y0

15   of the current pixel is replaced with the pixel whose value is the median MED amongst the five luminance values of the current pixels, East, North, West and South in the vicinity.

However, such a replacement preferably takes place only if this median value MED differs from the value Y0 of the current pixel only by a value Dmax less than a predetermined threshold, for example equal to 40 if the luminance values are between 0 and

20   255, that is to say in other words if:

$Abs(MED-Y0) < Dmax$, where $Abs(x)$ is the function which gives the absolute value of x. Thus such a filtering makes it possible to avoid making erroneous corrections.

In the contrary case, the value Y0 of the current pixel preferably remains unchanged, in order to reduce the complexity of the method. Nevertheless it can also be

25   envisaged opting for a median filtering of a set of pixels comprising the current pixel and some of the East, North, West and South pixels which are adjacent to it, depending whether these adjacent pixels are natural contour pixels or not, as described in the International patent application WO 2001/24115.

In a second embodiment, the post-processing method is implemented at a

30   video decoder. Compared with the embodiment previously described at the television receiver, the post-processing method can be improved and simplified by using the decoding information accessible at the decoder. The post-processing method then comprises the following steps:

- a step (200) of detecting pixels belonging to natural contours inside an image. As in the first embodiment, this natural contour detection step is based on the use of Sobel filters Sh and Sv. In this second embodiment, the predetermined threshold value T1, determined in an absolute manner from a certain number of sequences of digital images tested, is taken to be equal to 20000.

In addition, the chrominance component of a pixel is taken into account in addition to the luminance component. For this purpose, the natural contour detection is not applied directly to the chrominance values of the pixels of an image but is deduced from the luminance values as follows, illustrated in Fig. 4 in the case of an image format of 4:2:0 where there is a chrominance sample U and a chrominance sample V for 4 luminance samples Y. Thus a value A(47) of chrominance U or V (42) is deduced from the corresponding 4 final values a (43), b (44), c (45), d (46) issuing from the pixel detection step (200) applied to the luminance (41) in the following manner:

$$A = a \text{ OR } b \text{ OR } c \text{ OR } d$$

with a, b, c or d = 1 for a pixel with a natural contour and 0 otherwise.

Thus a chrominance sample is a sample belonging to a natural contour if at least one of the four luminance samples which correspond to it is a natural contour pixel.

The following steps are then the same for the luminance and chrominance components, namely:

- a step (210) of detecting an investigation zone (21) corresponding to a coding block. At the video decoder side, this step is easily performed because the coding blocks are directly accessible and therefore no longer require the steps of gradient filtering GF (211), calculation of absolute value (212), detection of blocking artifacts (213) and analysis (214);

- a filtering decision step (220): all the pixels belonging to an investigation zone containing at least one natural contour pixel and which are not natural contour pixels are intended to be filtered;

- a filtering step (230): the pixels to be filtered undergo a filtering, preferably median. This filtering depends on the quantization step QP of the coding block to which the pixel to be filtered belongs.

If the quantization step QP is strictly less than a first predetermined value Q1, no filtering is carried out, the quality of the coding being judged satisfactory.

If the quantization step QP is greater than or equal to the first predetermined value Q1 and less than or equal to a second predetermined value Q2, a median filtering identical to that described in the first embodiment is applied.

If the quantization step QP is strictly greater than the second predetermined value Q2, a strong correction must be applied. For this purpose, a mean filtering is applied using the values of a set of pixels comprising the current pixels and the East, North, West and South pixels which are adjacent to it.

Thus, if the pixel is not a natural contour pixel, its luminance value Y0 is replaced by the mean value Ymean:

$$Ymean = 1/5 * (Y0 + Y1 + Y2 + Y3 + Y4)$$

With:

- $Y1 = Y(East)$ if the East pixel is not a contour pixel and $Y1 = Y0$ otherwise,

- $Y2 = Y(North)$ if the North pixel is not a contour pixel and $Y2 = Y0$ otherwise,

- $Y3 = Y(West)$ if the West pixel is not a contour pixel and $Y3 = Y0$ otherwise,

- $Y4 = Y(South)$ if the South pixel is not a contour pixel and $Y4 = Y0$ otherwise.

Q1 and Q2 are values predetermined empirically, also respectively, for example at 5 and 20 in the case of the MPEG-4 standard, where the quantization step is between 1 and 31.

It is possible to implement the post-processing method according to the invention by means of a video decoder circuit or a television receiver circuit, said circuit being suitably programmed. A computer program contained in a programming memory can cause the circuit to perform the various operations described above with reference to Fig. 2. The computer program can also be loaded into the programming memory by the reading of a data medium such as for example a disk which contains said program. The reading can also take place by means of a communication network such as for example the Internet. In this case, a service provider will make the computer program available to interested parties in the form of a downloadable signal.

No reference sign between parentheses in the present text should be interpreted limitingly. The verb "comprise" and its conjugations should also be interpreted broadly, that is to say as not excluding the presence not only of elements or steps other than those listed after said verb but also a plurality of elements or steps already listed after said verb and preceded by the word "a" or "one".

CLAIMS:

1.   A method of post-processing pixels contained in a sequence of digital images, said method comprising:

          - a step (200) of detecting pixels belonging to natural contours (20) inside an image,

5   - a pixel filtering step (230),

          said method being characterized in that it also comprises a step (210) of detecting an investigation zone (21) corresponding to a coding block, a current pixel being filtered if it has not been detected as being a natural contour pixel (20) and if it belongs to an investigation zone (21) containing at least one natural contour pixel (20).

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2.   A post-processing method as claimed in Claim 1, in which the filtering step is able to use a median filter able to replace a current pixel with a pixel from a set comprising said current pixel and pixels surrounding the current pixel.

15 3.   A post-processing method as claimed in Claim 2, in which a replacement takes place only if a median value of the set of pixels differs from the value of the current pixel only by a value below a predetermined threshold.

4.   A post-processing method as claimed in Claim 1, in which the detection step is

20 based on a gradient filtering (201) using a filter of the Sobel type.

5.   A post-processing method as claimed in Claim 1, in which the natural contour detection step (200) comprises a refinement step (203) such that, if a vicinity comprising pixels surrounding a pixel detected as being a natural contour pixel, said vicinity containing

25 no other natural contour pixels, then said pixel is no longer assimilated to a natural contour pixel.

6.   A post-processing method as claimed in Claim 1, in which the filtering step is applied to a pixel in an investigation zone only if a quantization step for the corresponding coding block is greater than a predetermined value.

5   7.   A decoding method intended to provide decoded digital images and comprising a post-processing method as claimed in Claim 1, in order to post-process the decoded digital images so as to supply post-processed digital images.

8.   A device for post-processing pixels contained in a sequence of digital images,
10   said device comprising:
            - means for detecting pixels belonging to natural contours (20) inside an image,
            - pixel filtering means,
            said device being characterized in that it also comprises means for detecting an
15   investigation zone (21) corresponding to a coding block, the filtering means being configured so that a current pixel is filtered only if it has not been detected as being a natural contour pixel (20) and if it belongs to an investigation zone (21) containing at least one natural contour pixel (20).

20   9.   A video decoder able to supply decoded digital images and comprising a post-processing device as claimed in Claim 8, able to post-process the decoded digital images so as to supply post-processed digital images.

10.   A television receiver able to receive digital images and comprising a post-
25   processing device as claimed in Claim 8, able to post-process the digital images so as to display post-processed digital images on the screen of the television receiver.

11.   A computer program comprising a set of instructions which, when loaded into a circuit, causes the latter to perform the digital image post-processing method as claimed in
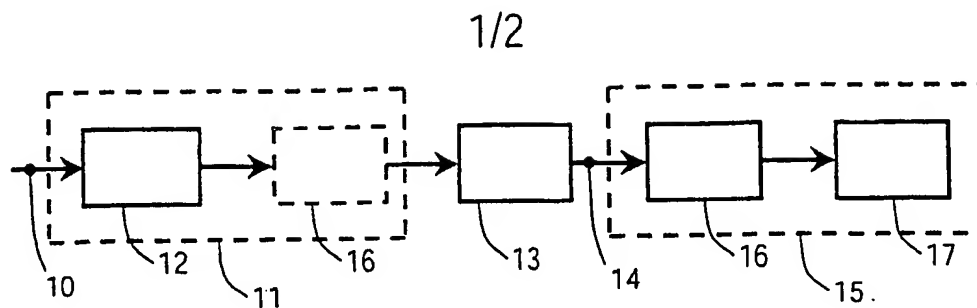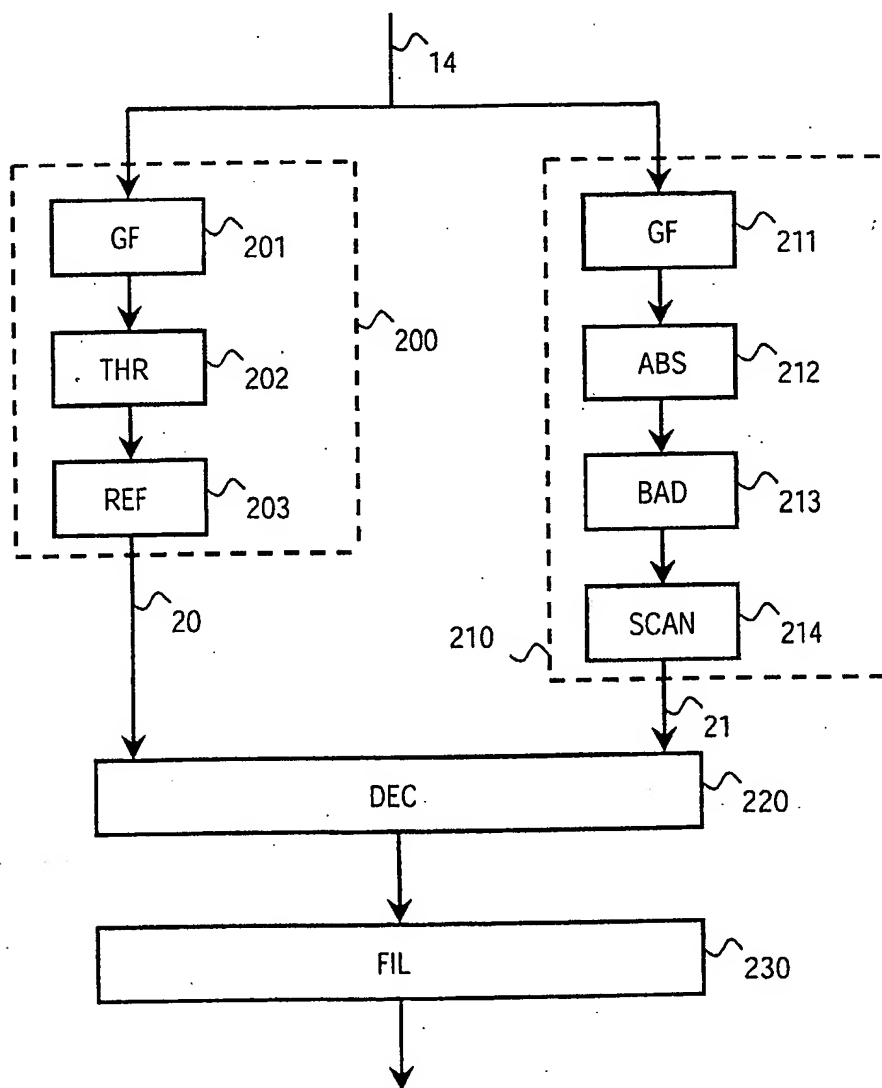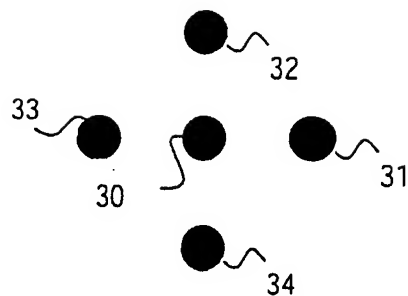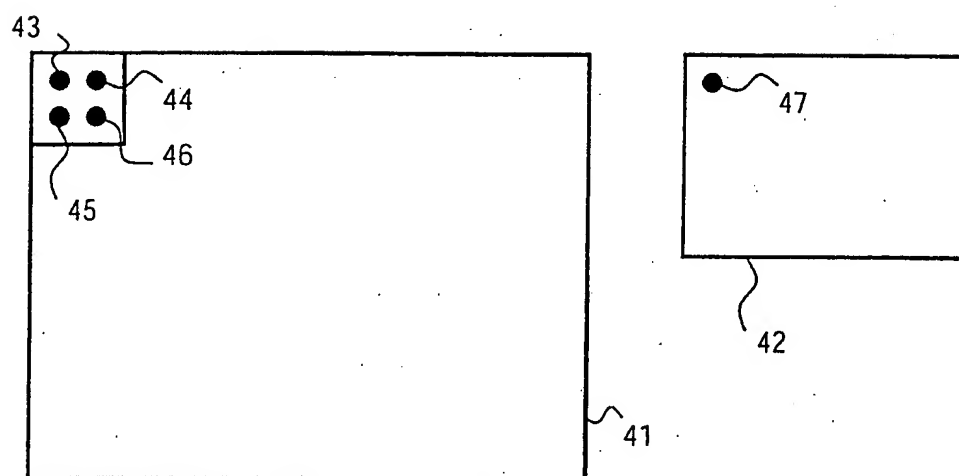30   Claim 1.

FIG.1

FIG.2

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FIG.3

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FIG.4

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   G06T9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7   G06T

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, INSPEC, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	ATZORI L ET AL: "A real-time visual postprocessor for MPEG-coded video sequences" SIGNAL PROCESSING. IMAGE COMMUNICATION, ELSEVIER SCIENCE PUBLISHERS, AMSTERDAM, NL, vol. 16, no. 8, May 2001 (2001-05), pages 809-816, XP004249808 ISSN: 0923-5965 page 811, left-hand column, paragraph 3 -page 812, left-hand column, paragraph 1 ---- -/--	1-11

[X] Further documents are listed in the continuation of box C.   [X] Patent family members are listed in annex.

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"A" document defining the general state of the art which is not considered to be of particular relevance

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Date of the actual completion of the international search	Date of mailing of the international search report
5 June 2003	12/06/2003

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Pierfederici, A

Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	HO Y-S ET AL: "CONTOUR-BASED POSTPROCESSING OF CODED IMAGES" PROCEEDINGS OF THE SPIE, SPIE, BELLINGHAM, VA, US, vol. 1199, no. PART 3, 1989, pages 1440-1449, XP000852904 page 1441, last paragraph -page 1442, paragraph 4 page 1446, paragraph 2 ---	1-11
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